ROTOR BLADE TIP SECTION

BACKGROUND OF THE INVENTION

[1] The present invention relates to a rotary wing aircraft rotor blade, and more particularly to a rotor blade tip spar arrangement.

[2] Conventional rotary wing aircraft rotor blades often include a tip section of a selected sweep, taper, and form to improve the blade performance. Anhedral tip sections increase hover performance and lift capabilities of a rotary wing aircraft on which the blades are fitted without increasing the structural features of the main rotor hub and spindle.

[3] The tip section of the main rotor blade is subjected to the greatest stresses/strains due to aerodynamic forces, and concomitantly experiences the greatest structural degradation due to wear and abrasion (due to the high rotational velocity of the main rotor blade tip), during operation of the helicopter main rotor assembly. These forces are only increased upon a tip section which utilizes an anhedral or other non-straight form.

[4] Disadvantageously, a tip section that utilizes a non-straight form may be relatively difficult and expensive to manufacture. For example, current anhedral tip sections require numerous structural components to carry the loads induced by the anhedral form. Current anhedral tip sections each require two structural anhedral tip skins and two structural honecomb core pieces along with non-structural pieces and redundant fasteners. Structural components may cost five times that of non-structural components. Furthermore, structural components require multiple expensive manufacturing, and in some instances proprietary, processes to produce the anhedral tip sections.

[5] Accordingly, it is desirable to provide an inexpensive rotor blade tip section that is applicable to anhedral form, minimizes the number of structural components, yet avoids adversely affecting the load bearing capabilities of the rotor blade.

SUMMARY OF THE INVENTION

[6] The main rotor blade according to the present invention provides a non-straight tip section, which includes a splice cap, a tip spar, a core and an upper and lower non-structural tip skin. The core and skins need not be structural members as the tip spar carries rotor blade tip section torsional loads. Relatively complex tip section forms that utilize a minimum of structural components are readily achieved by the present invention.

[7] The tip section is mounted to a central blade section by mounting the tip spar to a main blade spar. The tip spar includes a first surface substantially parallel to a second surface. The first and second surfaces each extend from a shear web therebetween to define a generally C-shape in cross section. The shear web generally carries rotor blade torsional loads and eliminates the heretofore required structural core. A section of the tip spar overlaps a section of the main blade spar. The tip section thereby transfers the loads carried thereby through interaction between the interaction of the overlapped spar sections.

[8] The present invention therefore provides an inexpensive rotor blade tip section that is applicable to anhedral form, minimizes the number of structural components, yet avoids adversely affecting the load bearing capabilities of the rotor blade.

BRIEF DESCRIPTION OF THE DRAWINGS

[9] The various features and advantages of this invention will become apparent to those skilled in the art from the following detailed description of the currently preferred embodiment. The drawings that accompany the detailed description can be briefly described as follows:

[10] Figure 1 is a top plan view of an exemplary main rotor blade assembly;

[11] Figure 2 is an expanded to plan view of a tip section of a rotor blade;

[12] Figure 3 is an expanded partial phantom perspective view of a tip section of a rotor blade;

[13] Figure 4 is a cross-sectional view of the main rotor blade of Figure 3 taken along line 3--3 thereof;

[14] Figure 5 is an exploded view of a tip section of a rotor blade;

[15] Figure 6 is an expanded partial phantom perspective view of an extended tip section of a rotor blade; and

[16] Figure 7 is an exploded view of a tip section of a rotor blade illustrated in Figure 6.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[17] Figure 1 illustrates a general perspective view of a helicopter rotor system 10 which includes a hub assembly 12 to be driven for rotation about an axis of rotation 13. A plurality of main rotor blade assemblies 14 project substantially radially outward from the hub 12 and are supported therefrom in conventional fashion by an attachment 15. Any number of blades 14 may be used with the rotor system 10. It should be understood that although a particular rotor system 10 is illustrated in the disclosed embodiment, other attachments, flex beams, main and tail rotors will benefit from the present invention.

[18] Each main rotor blade 14 includes a root section 16, a central section 18 of aerodynamic shape, and a tip section 20, which culminates in a blade tip 22. The blade sections 16, 18, 20 cooperate with the hub 12 to define a blade radius R between the axis of rotation 13 and the blade tip 22. A blade chord C extends between a blade leading edge 24 and a blade trailing edge 26.

[19] The blade 14 is fabricated with a selectively shaped tip section which includes a selected combination of rearward sweep, taper, dihedral, width, and anhedral. The tip section 20 operates to unload the blade tip 22, thereby producing a more uniform lift distribution throughout the span of the blade and also producing a more uniform downwash effect, as well as decreasing the power required to drive the rotor 10 and thereby increasing lift and hover performance. The tip section preferably reduces the intensity of the tip trailing edge vortex and also directs or displaces the tip trailing edge vortex so that it causes minimal interference on the following blade. The rotor blade tip section 20 preferably includes an anhedral form, however, other angled and non angled forms such as cathedral, gull, bent, and others will benefit from the present invention.

[20] Referring to Figure 2, each blade 14 includes a main blade spar 30 which extends from the root portion 16, through the central portion 18, and into the tip section 20 preferably prior to an anhedral droop 32 (Figure 3). The main blade spar 30 is a structural member having high torsional and axial stiffness and strength, and in the preferred embodiment is made of a high strength composite material. However, the spar may also be made from a high strength metal,

such as titanium. The blade 14 extending from the root portion 16 and through the length of the central portion 18 preferably include a core material covered by a composite skin (illustrated schematically at 31; Figure 3) which defines the aerodynamic shape of the blade as generally known.

[21] Referring to Figure 4, a sectional view of the tip section 20 is illustrated. The tip section 20 includes a splice cap 34, a tip spar 36, a core 38, and an upper and lower non-structural tip skin 40, 42 (also illustrated in an exploded format in Figure 5). The tip spar 36 is preferably the only structural component within the tip section 20.

[22] The splice cap 34 is made of a wear-resistant material, such as nickel to provide abrasion protection for the tip section 20. The splice cap 34 also provides control of airfoil tolerances of the tip section 22. The splice cap 34 preferably attaches to an open end 44 of the generally C-shaped tip spar 36 and overlays the forward edges of the skins 42, 44. The splice cap 34 and tip spar 36 mount directly to the main rotor main blade spar 30 (Figure 3) to provide a rigid structure which supports the loads induced by the tip section 20 with a minimum of structural components. The splice cap 34 and tip spar 36 are preferably bonded to the main rotor main blade spar 30 and additionally may include redundant fasteners. An adhesive material, such as epoxy film adhesive, is a preferred bonding agent.

[23] The tip spar 36 preferably includes a first surface 46 substantially parallel to a second surface 48. The first and second surfaces 46, 48 each extend from a shear web 50 therebetween to define the generally C-shape in cross section. The shear web 50 generally carries rotor blade torsional loads and eliminates the heretofore required structural core.

[24] The first and second surfaces 46, 48 and shear web 50 need not be planar and need not be of consistent thickness. That is, a more rounded C-shape in cross section, a U-shape in cross section or other combinations of shapes which generally mate with a main rotor spar will benefit from the present invention.

[25] The tip spar 36 defines a first spar section 52 angled relative a second spar section 54. That is, the first spar section 52 generally extends along an axis defined by the main rotor main blade spar 30 and the second section is angled relative thereto to define an anhedral form. It should be understood that the tip spar 36 may alternatively include multiple sections angled

relative to each other to define other tip sections such as a multi-angled cathedral tip section 20a (Figures 6 and 7). Relatively complex forms are readily achieved by the present invention.

[26] Preferably, the tip spar 36 is manufactured from IM7 graphite material in female mold, vacuum bagged and cured as generally known. The tip spar 36 may then be NDI inspected as also generally known. It should be understood various manufacturing processes will also benefit from the present invention.

[27] The tip section 20 is mounted to the central section 18 by mounting the tip spar 36 to the main blade spar 30. The tip spar 36 is mounted to the main blade spar 30 through bonding, however, other removable attachment arrangements will also benefit from the present invention such that the tip section 20 is field replaceable.

[28] Referring to Figure 5, a section S1 of the tip spar 36 overlaps a section S2 of the main blade spar 30. That is, sections S1, S2 fit in a male female relationship. Preferably, the center of the overlap is located at approximately 91.5%R (Figure 2). It should be understood that other overlap length and locations will also benefit from the present invention. The inner perimeter P1 of section S1 and the outer perimeter P2 of section S2 are preferably reduced such that a flush surface joint is formed therebetween (Figure 4). It should be understood that other interfaces will also benefit from the present invention. The tip section 20 thereby transfers the loads carried thereby through interaction between the interaction of the sections S1 and S2.

[29] The core 38 is preferably a one-piece non-structural member as the tip spar 36 carries rotor blade tip section torsional loads. The core is preferably a non-formed, low-density core piece of a three pound density which replaces conventional multiple structural cores thereby reducing part count and machining operations.

[30] The upper and lower non-structural tip skin 40, 42 are preferably non-structural skins such as a three ply fiberglass lay-up. Alternatively, the skins are formed using layers of graphite fiber and fiberglass fiber such that the skins include three layers of fiberglass fiber, and in the leading edge of the blade, where the blade is subject to the greatest wear and tear, layers of graphite fiber are added to further enhance the strength and durability of the skin.

[31] Referring to Figure 6, another blade assembly 14A is illustrated. The tip spar 35A is of an extended length and includes an extended splice cap 34A (Figure 7), which forms the leading

edge of both the tip section 20A and intermediate section 18A. It should be understood that other confirmations which also essentially integrate the tip and intermediate sections 20, 18 will benefit from the present invention. That is, the present invention is applicable to sections of a rotor blade other than just the tip section.

[32] The foregoing description is exemplary rather than defined by the limitations within. Many modifications and variations of the present invention are possible in light of the above teachings. The preferred embodiments of this invention have been disclosed, however, one of ordinary skill in the art would recognize that certain modifications would come within the scope of this invention. It is, therefore, to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described. For that reason the following claims should be studied to determine the true scope and content of this invention.